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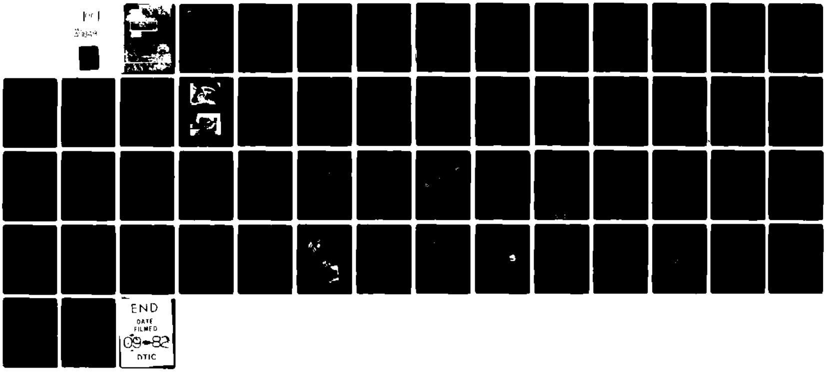

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Since eye movements are required for the detection and tracking of a point target, their concomitant signal can provide physiological objective measures of performance in target acquisition tasks. Saccadic latency, misses, and false alarm rate were used in assessing and comparing the effects of static and dynamic masks on target detection and tracking. A point target with an effective diameter of 0.4 degrees was displayed in either of two fixed positions separated by 18 degrees symmetrically with respect to the egocentric axis. Timing of target displacement was either periodic, or aperiodic. The

masking field was generated by projection of a polarized texture pattern, characterized by a spatial spectrum below 1 cpd, superimposed on the visual axis via a beam splitter. Masking dynamics were generated by a rotating polarizer situated in front of the masking field projector. As target luminance decreased from 11 to 6 ft-L, reaction time measured as saccadic latency, increased. This effect of target luminance was further substantiated once static masking was introduced. Aperiodic target displacements resulted in false alarm saccades to the right position. It was found that dynamic mask of the same spatial spectrum and contrast had a significantly more detrimental effect on subject performance. This was manifested by longer reaction times and higher rates of misses and false alarms. In tracking a constant-velocity smoothly moving target, masked by a fixed intensity of video "snow-noise", there was 2-3 fold increase in r.m.s. of tracking-error measured over less than 1 log unit attentuation range of point-target intensity.

MASKING EFFECTS ON VISUAL TARGET DETECTION AND TRACKING

Yehoshua Y. Zeevi
Man Vehicle Laboratory
Massachusetts Institute of Technology
Cambridge, MA 02139

AFOSR-81-0135
Final Research Report

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Background

Technological advances in wide field-of-view computer generated imagery (CGI) representations of visual scenarios in flight simulation have not been matched by adequate development of objective measures and techniques for assessing the utility of the displayed information vis-a-vis pilot's performance. As one strives to develop enriched visual scenes providing the necessary perceptual fidelity, the question arises, what are the important display characteristics that contribute to minimally acceptable levels of behavioral fidelity? Specifically, objective measures are required in evaluation of display systems and of the generated imagery.

It is apparent from various studies that when the visual scene subtends a wide angle, as is the case for actual flights and the Advanced Simulator for Pilot Training (ASPT), eye movements are required for the detection and tracking of a target and/or for the recognition of a visual pattern (Yarbus, 1967; Senders, 1978). Such eye movements externalize some aspects of information processing in the visual system, and as such can be utilized as an objective physiological measure of psychophysical functions. Further, we often have observed that when required to report the detection of a target or a patch of test pattern under unfavorable signal-to-noise ratio conditions, subjects fail to "detect" the target or test pattern whereas they do foveate it. This indicates to us that the detection task was achieved at the lower level of processing of visual information. However, because of response criteria and other behavioral factors, this detected signal did not suffice at the decision level.

In the present series of experiments, begun at the Air Force Human Resources Laboratory at Williams Air Force Base (Zeevi, 1980), we intended to adopt this approach in evaluation of masking effects on visual target detection and tracking. The preliminary results summarized in this report indicate that objective measures of behavioral components, assessing masking effects, can indeed by extracted from eye movement responses. However, further refinement of the study would require a special purpose facility for generating dynamic band-limited noise. As it became clear early in this research program that such a facility will be developed under a related research contract at Harvard University (Kronauer, 1981), we decided to extend, instead, under the minigrant program, another interrelated facet of our research on visual aspects of flight simulations. Thus, the major portion of this report is devoted to our investigation of motion-in-depth induced by viewing dynamic visual noise with intraocular intensity difference. This study too was conducted in collaboration with the OT/AFHRL of Williams AFB.

MASKING EFFECTS ON VISUAL TARGET DETECTION AND TRACKING

Yehoshua Y. Zeevi
Man Vehcile Laboratory
Massachusetts Institute of Technology
Cambridge, MA 02139

T.M. Longridge and J.C. De Maio
Air Force Human Resources Laboratory
Williams AFB, AZ 85224

This work was supported in part by AFOSR Grant 81-0135

ABSTRACT

Since eye movements are required for the detection and tracking of a point target, their concomitant signal can provide physiological objective measures of performance in target acquisition tasks. Saccadic latency, misses, and false alarm rate were used in assessing and comparing the effects of static and dynamic masks on target detection and tracking. A point target with an effective diamater of 0.4° was displayed in either of two fixed positions separated by 18° symmetrically with respect to the egocentric axis. Timing of target displacement was either periodic, and as such may have affected predictive control, or aperiodic. Masking field was generated by projection of a polarized texture pattern, characterized by a spatial spectrum below 1 cpd, superimposed on the visual axis via a beam splitter. Masking dynamics were generated by a rotating polarizer situated in front of the masking field projector. As target luminance decreased from 11 to 6ft-L, reaction time measured as saccadic latency increased. This effect of target luminance was further substantiated once static masking was introduced. Aperiodic target displacements resulted in false alarm saccades to the right position. It was found that dynamic mask of the same spatial spectrum and contrast had a significantly more detrimental effect on subject performance. This was manifested by longer reaction times and higher rates of misses and false alarms. In tracking a constant-velocity smoothly moving target, masked by a fixed intensity of video "snow-noise" there was 2-3 fold increase in r.m.s. of tracking-error measured over less than 1 log unit attentuation range of point-target intensity.

The primary function of the oculomotor control system is the acquisition of visual information. In most scan and search tasks this is accomplished by the saccadic system which samples sequentially, as it foveates new areas of potential interest, at a rate of up to four samples per second. When a subject is instructed to fixate on a point target, and the target is suddenly shifted to a new position, about 200 msec elapse between the shift of the target and the onset of saccadic eye movement towards the new position (Westheimer, 1954). This effect, known as saccadic latency, is dependent on a variety of factors, such as target luminance and contrast (Wheeless et al, 1967) and task complexity (Zeevi and Peli, 1979; Wetzel and Zeevi, 1981). It is also known that practice and target predictability may shorten this time (Hackman, 1940; Stark et al, 1962; Zeevi and Peli, 1979), whereas fatigue may lengthen it (Miles, 1963).

The present research is concerned mostly with measurements of saccadic eye movements for the assessment of subjects' performance, and evaluation of display characteristics relevant to point-target detection and saccadic and smooth pursuit tracking tasks. Dual targets are currently being investigated in our laboratory under a separate research program (Young and Zeevi, 1981). The research summarized in this part of the report concerns the question of whether dynamic noise is more effective than its static counterpart, characterized by the same spatial frequency spectrum, in masking point targets in so far as detection and tracking tasks are considered.

The experimental setup and a schematic representation of the setup used originally (at AFHRL Williams AFB) are shown in Figs. 1 and 2 respectively. Eye movements were recorded first using a modified G&W Model 200 Eye Track monitor, and later implementing the same concept of infrared limbus tracking in an in-house designed system (Fig. 1a). The eye movement monitor consists of a balanced bridge photodetector circuit, the output of which is differentially amplified, corrected for D.C. offset, then amplified again. Accurate horizontal eye position (±0.1 degree) could be obtained within the range of ±30 degrees. In the original setup (Fig. 2), the video monitor, which is part of the EyeTrac system, served both as the secondary visual feedback (Zeevi et al 1979; Zeevi and Peli, 1979) and target display. These were later displayed separately and were superimposed via a beam splitter (Fig. 1b). The masking field in the saccadic tracking tasks was generated by projection of a polarized texture. Masking dynamics were generated by rotating a polarizer situated in front of the masking field projector. It is estimated that most of the texture spatial spectrum was below 1 cpd. In the experiments evaluating smooth pursuit tracking error, as a function of signal-to-noise ratio, we used video noise generated by detuning a television receiver. The relative S/N was defined by the attentuation of the target intensity using neutral density filters.

The data summarized in Fig. 3 demonstrates that, as target luminance decreases, saccadic latency increases. Note that in most cases the variability is much smaller at higher luminance. This is consistent with previous findings (Wheeless et al, 1967) and should be taken into consideration in the design of simulator display systems. The effect of target luminance on saccadic latency is further substantiated once masking noise is introduced. This too is consistent with a previous result demonstrating that noise masking is more effective than coherent masking at the same contrast level (Stromeyer and Julesz, 1972; Gafni and Zeevi, 1977). However, this study was concerned with detection and masking of spatial frequency whereas our study is devoted to point target detection and tracking.

The dynamic aspect of vision is all too often overlooked and most vision research has been dedicated to processing of spatial information. However, information flow in both actual flight and flight simulators is obviously dynamic as are the characteristics of noise generated by display systems. It is therefore important to compare the masking effects of static and dynamic noise on target detection and tracking. The results shown in Fig. 4 clearly demonstrate that compared with static noise, dynamic noise of the same spatial spectrum and contrast has a significantly more detrimental effect on subjects' performance. This effect is manifested by both longer reaction times and a higher rate of misses and false alarms. This should be expected in view of the fact that visual channels at the preprocessing stages are endowed with spatio-temporal characteristics and as such are likely to mediate the corresponding spatio-temporal masking effects on saccadic latency.

Dynamic noise has also significantly effected performance in smooth pursuit tracking tasks. Here we found a consistent increase in the r.m.s of tracking-error with decrease in S/N (Fig. 5). It is important to point out that, although this is not documented by data in this report, here too the dynamic noise had significantly more detrimental effects on subject performance manifested both in the r.m.s. tracking error and response latency.

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FIGURE CAPTIONS

Figure 1: Infrared transducer for eye movement measurements (a), and experimental setup for target tracking and detection tasks (b).

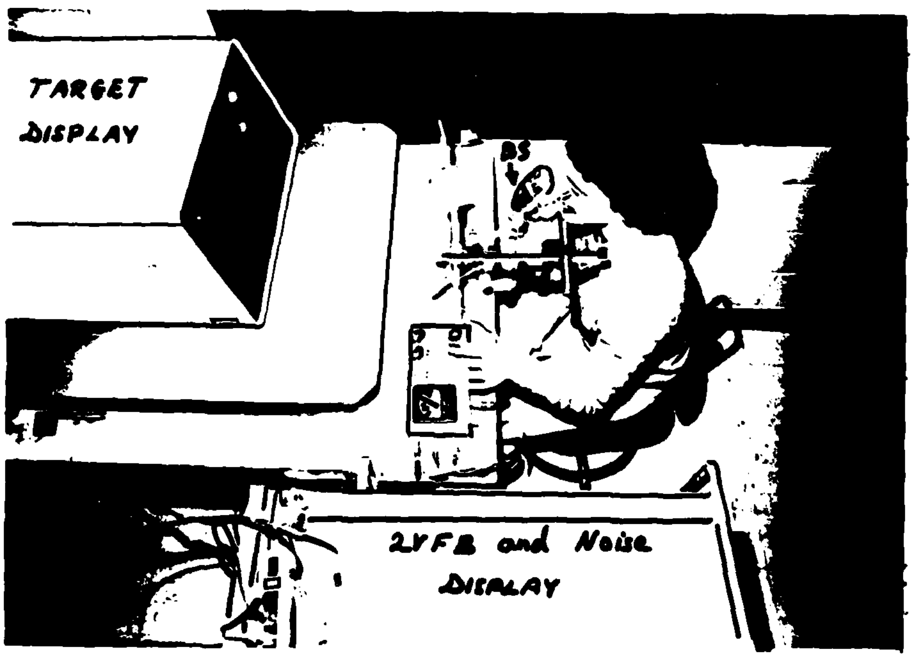
Figure 2: Schematic diagram of setup for eye movement measurements.

Figure 3: Saccadic latency in tracking periodic (circles) and aperiodic (squares) point-target vs. target luminance.

Figure 4: Masking effects on saccadic latency in tracking periodic (a) and aperiodic (b) targets. Circles denote tracking with no noise, x's - masking by static noise, and squares - masking by dynamic noise.

Figure 5: R.m.s. of smooth pursuit tracking-error as a function of relative target attentuation.

(a)



(b)

FIGURE 1

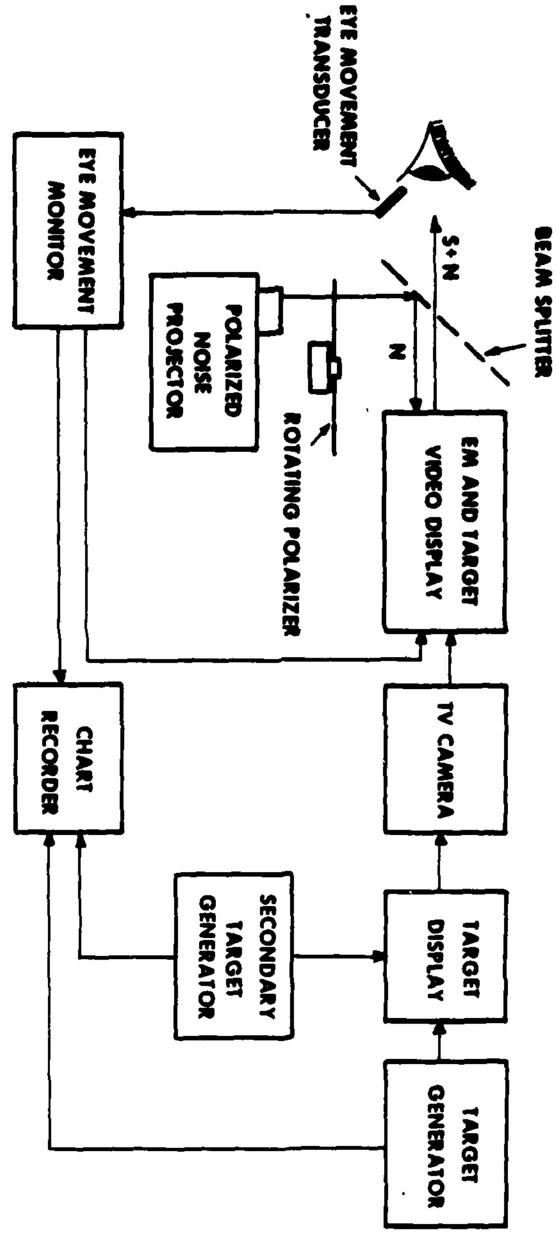
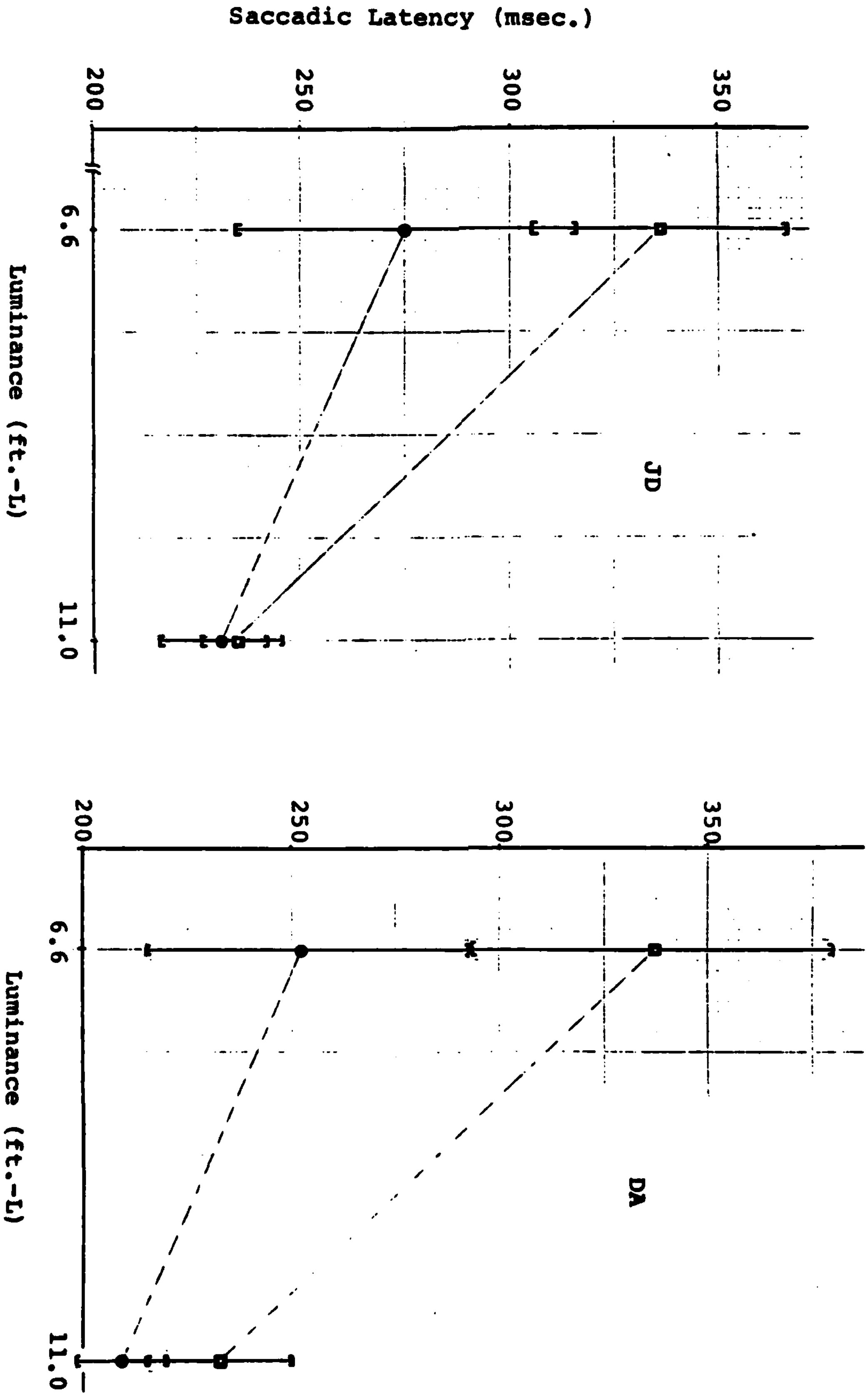

EYE MOVEMENT TRANSDUCER
BEAM SPLITTER
S+N
N
EYE MOVEMENT MONITOR
POLARIZED NOISE PROJECTOR
ROTATING POLARIZER
EM AND TARGET VIDEO DISPLAY
TV CAMERA
TARGET DISPLAY
TARGET GENERATOR
SECONDARY TARGET GENERATOR
CHART RECORDER

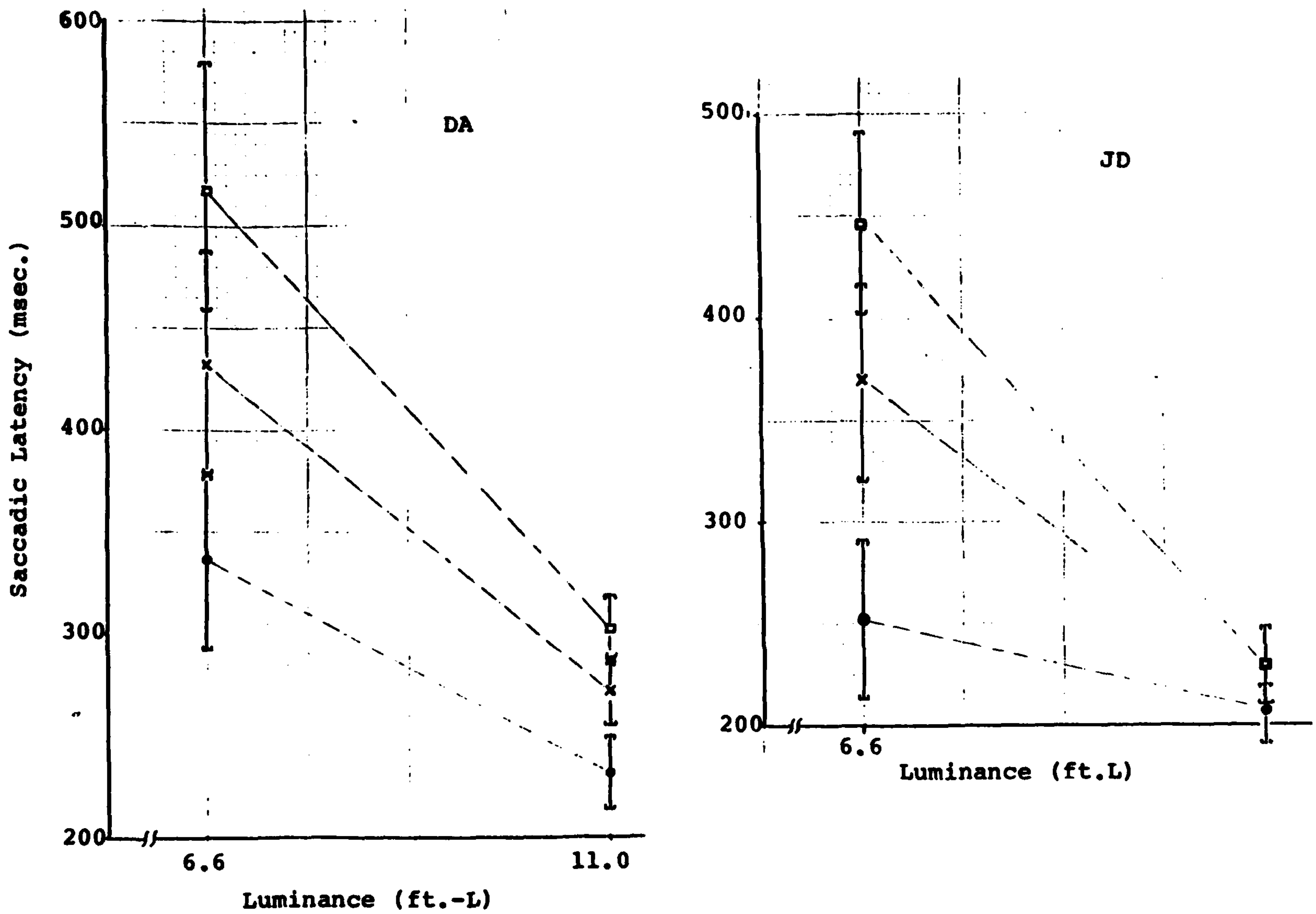
Fig. 2



Saccadic Latency (msec.)
200
250
300
350
6.6
11.0
Luminance (ft.-L)
JD
DA

FIGURE 3

FIGURE 4


Saccadic Latency (msec.)
600
500
400
300
200
DA
6.6
11.0
Luminance (ft.-L)
500
400
300
200
JD
6.6
Luminance (ft.L)

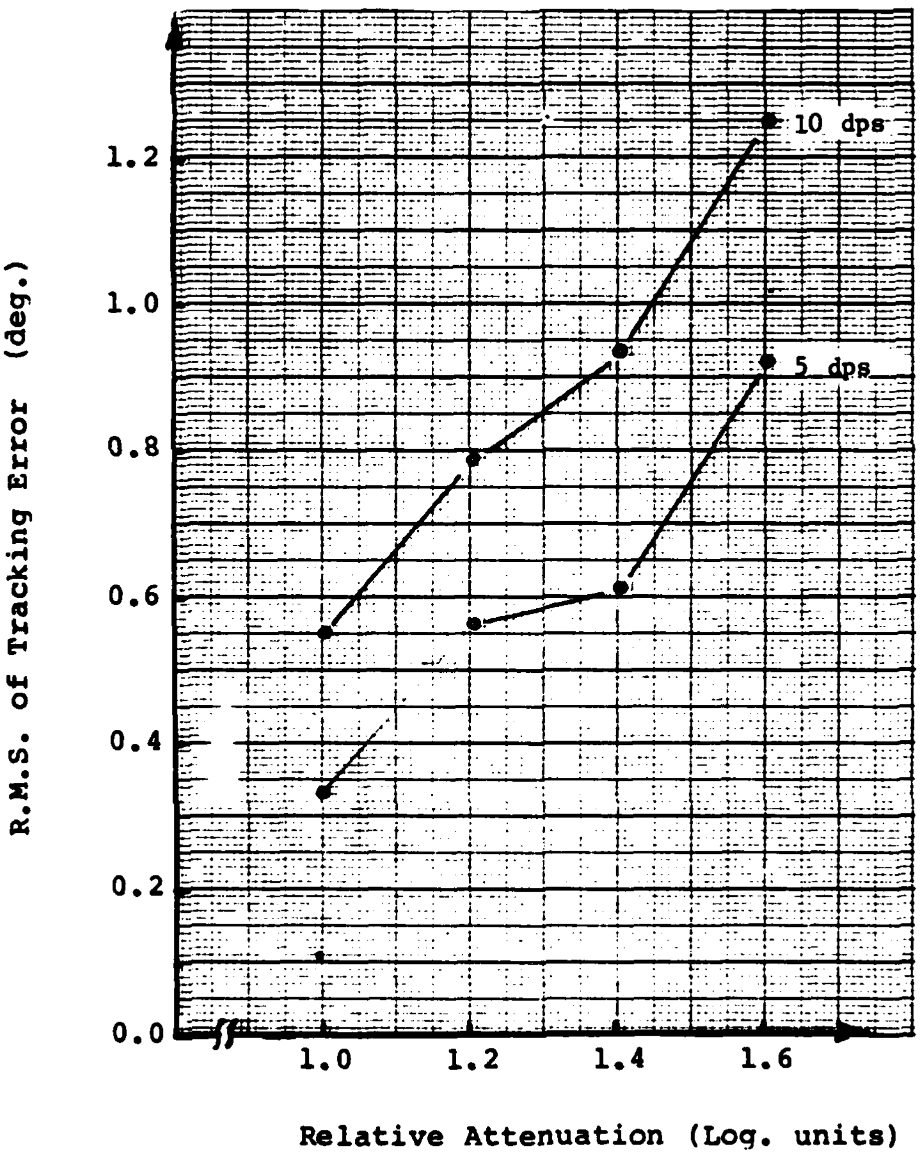

10 dps
5 dps
1.2
1.0
0.8
0.6
0.4
0.2
0.0
R.M.S. of Tracking Error (deg.)
1.0
1.2
1.4
1.6
Relative Attenuation (Log. units)

FIGURE 5

VISUAL ACCELERATION PERCEIVED WITH DYNAMIC NOISE

Y.Y. Zeevi and A. Medina
Man-Vehicle Laboratory
Massachusetts Institute of Technology
Cambridge, MA 02139

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VISUAL ACCELERATION PERCEIVED WITH DYNAMIC NOISE

Y.Y. Zeevi and A. Medina
Man-Vehicle Laboratory
Massachusetts Institute of Technology
Cambridge, MA 02139

ABSTRACT

The velocity of apparent movement, induced by the dynamic visual noise version of the Pulfrich effect, increases during tracking of the perceived moving textured-plane. Eye movements recorded while tracking the perceived moving plane show consistent acceleration, reaching a maximum velocity ten times greater than that estimated during fixation. It is suggested that this gradual increase in perceived velocity is due to a continual updating of the perceived velocity by the efferent copy of the oculomotor control signal. The latter is intended to compensate for the centrally-induced motion, but cannot since the system operates under a functional open-loop condition.

INTRODUCTION

When a field of dynamic visual noise is binocularly viewed with an interocular delay or intenisty difference it is perceived, after a period of adaptation, as a coherent motion-in-depth (Ross, 1974; Tyler, 1974). There are individual differences in how the effect is perceived, however, for most observers it appears to consist of two counter-directionally moving textured-planes separated in depth (Mezrich and Rose, 1977; Zeevi et al, 1982). The perceived front plane protruded with respect to the plane of display, seems to laterally move in the direction of the filtered (attenuated) eye, whereas the recessed back plane appears to move in the opposite direction.

Subjects can estimate its velocity while they attend to, and fixate on, one of the moving planes. Alternatively, they can track it, in which case they report that the perceived velocity appears to increase. This qualitative general observation was also previously reported (Tyler, 1974; Falk and Williams, 1980). We have further noticed that this phenomenon is associated with a gradual increase in perceived velocity -- i.e. the dots, or speckles, actually seem to accelerate when tracked.

Since the smooth pursuit mode of the oculomotor system is controlled by the perceived continuous motion relative to the head (Steinbach, 1976; Young, 1977), eye movement measurements should provide a physiological correlate of the perceived texture-streaming-velocity. Further, since an efferent copy of the oculomotor control signal is believed to be fed back and to carry a position (and velocity) correction signal (Helmholtz, 1962) eye movements can be expected to effect the magnitude of the perceived velocity. We have therefore studied the trajectories of eye movements of several experienced and novice subjects, as they tracked one of the moving planes, and compared their maximum velocity with the induced velocity estimated while fixating on the same plane.

APPARATUS AND PROCEDURE

Dynamic visual noise has been generated in other studies of the motion stereophenomenon in a variety of ways (Ross, 1974; Tyler, 1974; Mezrich and Rose, 1977; McDonald, 1977; Falk and Williams, 1980; Zeevi et al, 1982). Of these we have selected the noise generated by detuning a television receiver; we found this simple to implement technique most adequate for our experiments. Most of the experiments were carried out using a black and white television receiver (mean luminance of about 25 ft-L and contrast of about 60%) subtending a visual angle of about 13 degrees horizontally when viewed from a distance of 22 inches. The observer viewed the display with his head immobilized by means of a headrest, and in the case of eye movement recordings, used also a bite bar.

A second display situated at a right angle to the TV monitor was superimposed on the visual field of the right eye via a beam splitter (Fig. 1). This was used for generating a constant velocity point-target in velocity matching experiments. Alternatively, in some of these experiments, a travelling square-wave grating of spatial frequency matching the grain-size of the dynamic visual noise was generated on the second display. A neutral density filter (1.0 N.D.) was placed in front of the right eye so that the total relative attentuation of this eye was equivalent to 1.3 log units. Movement of the left eye was monitored using an infrared limbus tracking device (Bandwidth 1KHz).

Six subjects participated in the experiments; three had previous experience with this stereophenomenon, and the others observed it for the first time in these experiments. After adapting to the dynamic noise for about a minute until coherent movement was reported by the observer, the constant-velocity point-target was superimposed on the right eye's visual field. Subjects were instructed to match the velocity of the perceived recessed plane with the velocity of the repetitive moving point by adjusting the frequency of a saw-tooth generator controlling the sweep velocity. To minimize tracking of the travelling spot and/or perceived plane, a fixation point attached to the display was required.

The eye movement monitor was next calibrated in preparation for the tracking experiment by having the subject fixate the left and right edges of the TV display as well as its center fixation-point. Subjects were asked to track the perceived coherent movement, while the left eye movements were monitored and sampled by a PDP 11/34 at a rate of 200 samples per sec. (thus reducing the effective bandwidth to 100 Hz). Following the experiment, subjects were asked to describe the qualitative characteristics of the movement perceived in the tracking mode.

RESULTS

When a neutral density filter was placed over one eye, all observers reported the appearance of coherent motion-in-depth. The most common description of the perceived effect was that of two counter directionally moving textured-planes separated in depth. Occasionally, though, subjects described the effect as that of a distribution in depth of moving planes, similar to the description reported by Tyler (1974). While fixating the center of the dynamic visual noise display, all observers reported that they could selectively attend one of two perceived moving planes. The matching velocity task has proven to be more difficult than expected, for inexperienced subjects. Apparently it was difficult for them to suppress their tendency to track the moving point-target, as was reflected in the eye movement measurements. The first estimate was therefore much higher than the subsequent estimates (in consistence with the general observation that the perceived velocity increases in tracking), especially when a subject was eager to obtain a quick result, and was excluded in the calculation of the mean velocity. A typical complaint, under these circumstances of having short episodes of pursuit eye movements, was that the velocity changed as soon as a match was achieved. In subsequent sessions, when observers were encouraged to take their time and attempt to better fixate, lower estimates were consistently obtained. Each of the velocities shown in Table 1 (left column) represents the mean of 2 to 5 sessions of self adjustments. These are within the range of velocities obtained in other studies (Falk and Williams, 1980; Zeevi et al 1982).

Tracking the apparent movement was not an easy task either for inexperienced subjects, but after a few trials all those who participated in these experiments succeeded and generated smooth pursuit trajectories in most cases free of saccadic interruptions. (None of these were capable of releasing smooth eye movements in the absence of sensory stimulus regarding movement). Invariably all the observers reported some sort of an increase in perceived velocity due to tracking. Some described the effect as an abrupt, sudden, increase to a much higher velocity than that perceived during fixation, as if it were an all-or-none effect. Experienced subjects, though, described it as a gradual increase in velocity indicative of some sort of continuous acceleration. Indeed, in as much as one can infer about perceived velocity from eye movement trajectories, and we shall later pursue this idea, our results indicate that the latter better described the phenomenon (Fig. 2). The maximum velocity recorded during tracking was in the range of 25 -50 deg/sec -- about a ten fold increase in velocity compared with that estimated in the fixation mode. Each of the velocities summarized in Table 1 (right column), represents the mean of 6-12 maxima of the derivatives computed for saccade-free tracking responses. It is interesting to note that already over such a short distance of less than ten degrees the smooth pursuit oculomotor control system had accelerated the eyes to a velocity somewhat higher than what most often is claimed to be attainable (Young, 1981).

DISCUSSION

Tyler (1974) was the first to observe that movement is enhanced by tracking. This observation was substantiated by Falk and Williams (1980) who reported that the more they attempted to track the coherent motion, the higher appeared to be its perceived velocity. They also correctly argued, albeit reverting to an oversimplistic explanation, that the perceived velocity is derived from the combination of eye velocity and other sources of movement information, but stopped short of concluding and/or observing that this situation results in a perceived acceleration along with its concomitantly driven accelerated eye movement.

It was previously shown by Steinbach (1976) that a centrally-derived motion percept can provide a sufficient control signal for the pursuit system. Our results illustrated in Figure 2 further corroborate this concept, and also complement those of Bozkov et al (1976) on the saccadic system by showing, in analogy, that the pursuit system can track visual movement that does not exist monocularly. In this regard, our experiments are similar to those of Steinbach and Anstis (briefly discussed, but not documented in Anstis (1980)), in which they generated moving stero gratings using Julesz's technique of dynamic random-dot stereo-cinematography, and also observed tracking with smooth eye movements. It should be noted however that with the dynamic visual noise used in our experiments, there does not exist any explicit positional or form (edge) information either monocularly or at the level of the cyclopean perception. The component of the perceived velocity induced by the interocular intensity difference is therefore independent of eye position and eye movements can in no way compensate for, or reduce it. The unity negative feedback loop (Fig. 3) is, under these circumstances, functionally opened, similar to other open loop situations (Young and Stark, 1963; Robinson, 1965; Zeevi et al 1979). It is so because the efferent copy of the eye movement command signal closes a positive feedback loop as is depicted in the schematic diagram of Figure 3. When an attempt is made to track the induced movement, the eye velocity is added to the perceived velocity. This information generates in turn a new eye movement command signal of higher velocity. Thus, this positive feedback loop gives rise to a perceptual effect of acceleration of the moving textured plane as is reflected in its concomitant exponential trajectory of eye movements.

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Table 1: Comparison of velocities induced in fixation and tracking modes

Subject	Velocity estimates in fixation mode [deg/sec]	Maximum induced velocity in tracking mode [deg/sec]
AM	3.5	38
JM	3.5	25
IM	2.0	30
JW	2.1	42
JI	*	32
YZ	5.3	47

* Subject JI found it difficult to match the velocities while fixating the center of the display.

FIGURE CAPTIONS

Figure 1: Schematic diagram of setup for estimation of perceived velocity induced by visual dynamic noise with interocular intensity difference in fixation and tracking modes of observation.

Figure 2: Typical examples of eye movement trajectories recorded during tracking of one of the perceived moving textured-planes. The trajectories exhibit acceleration with exponential time course, decelerating towards the edge of the dynamic noise display. Dotted-lines indicate filtering of blinks.

Figure 3: A simplified scheme depicting the basic hypothesis of how the efferent copy gives rise to a perceptual acceleration during the tracking of motion induced by dynamic visual noise with interocular intensity difference (for further explanation see text).

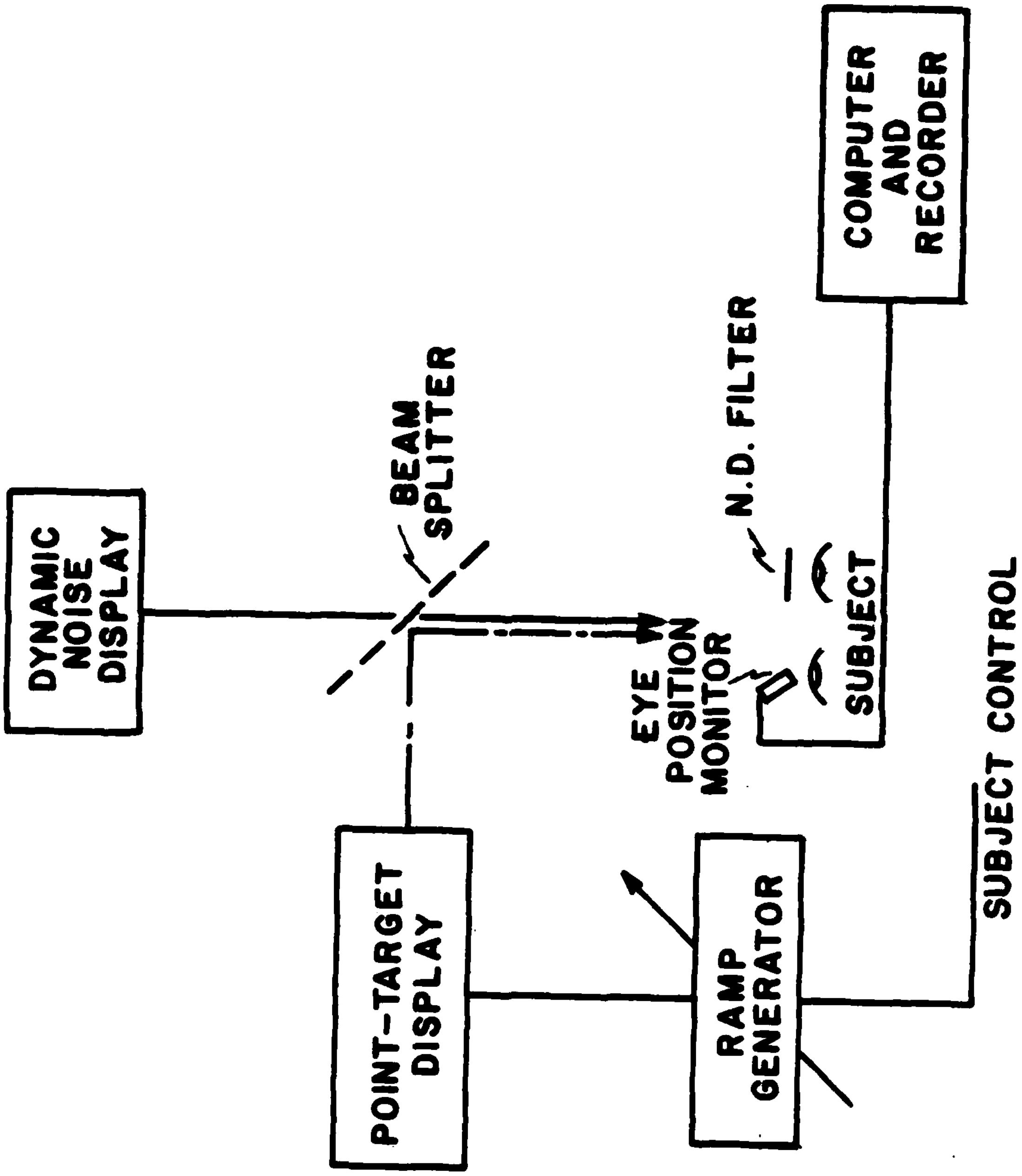
DYNAMIC
NOISE
DISPLAY
BEAM
SPLITTER
N.D. FILTER
COMPUTER
AND
RECORDER
EYE
POSITION
MONITOR
SUBJECT
POINT-TARGET
DISPLAY
RAMP
GENERATOR
SUBJECT CONTROL

FIGURE 1

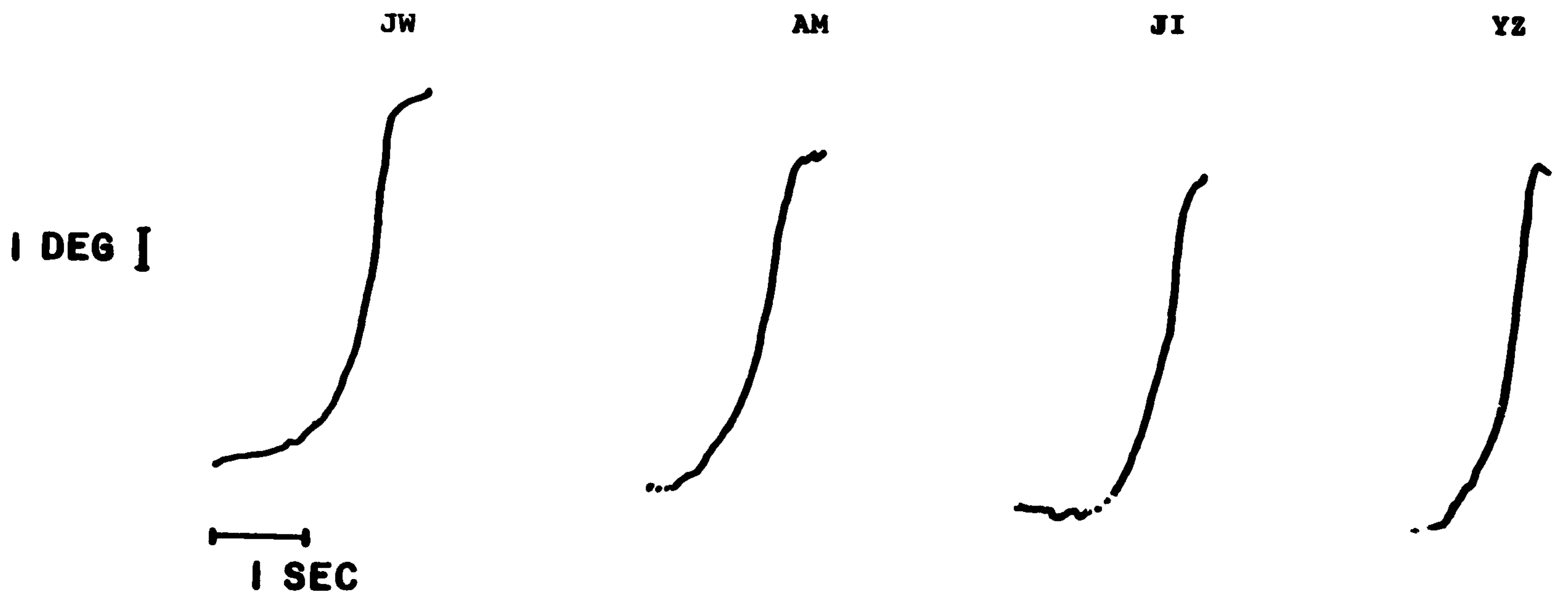

FIGURE 2

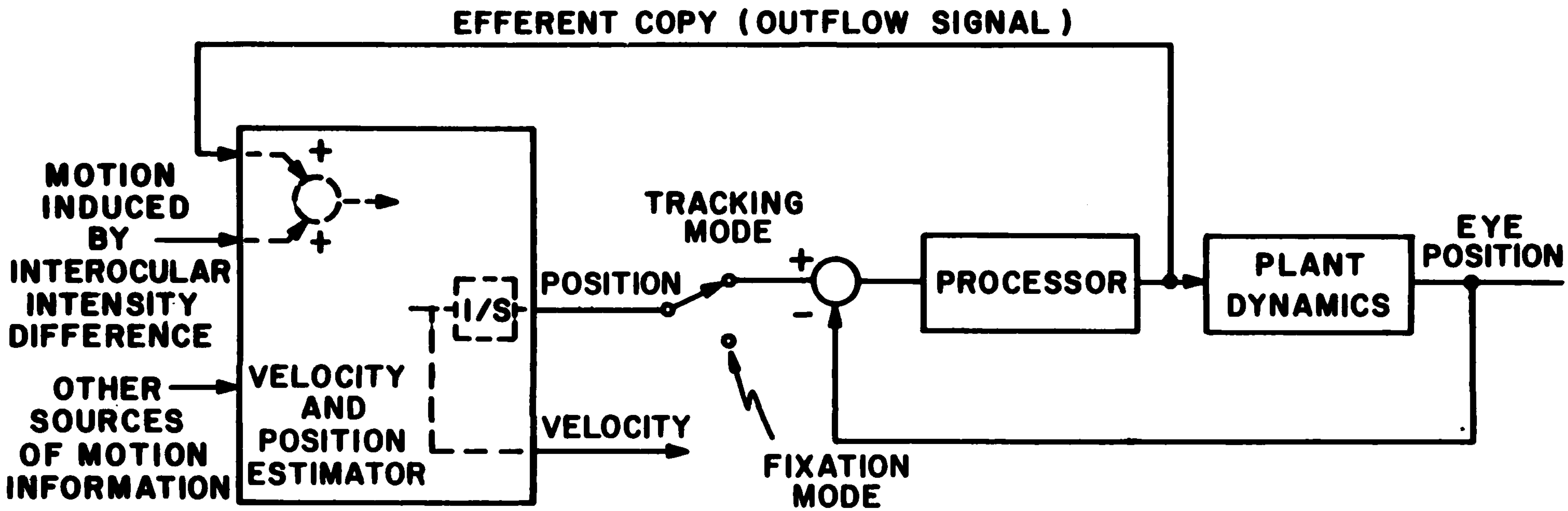
EFFERENT COPY (OUTFLOW SIGNAL)
MOTION INDUCED BY INTEROCULAR INTENSITY DIFFERENCE
OTHER SOURCES OF MOTION INFORMATION
VELOCITY AND POSITION ESTIMATOR
I/S
POSITION
VELOCITY
TRACKING MODE
FIXATION MODE
PROCESSOR
PLANT DYNAMICS
EYE POSITION

FIGURE 3

Selective Rivalry Suppression and Motion Aftereffect in Binocular Viewing of Dynamic Noise

Yehoshua Y. Zeevi
Man Vehicle Laboratory
Massachusetts Institute of Technology
Cambridge, MA 02139

and

George A. Geri and Thomas M. Longridge
Air Force Human Resources Laboratory
Williams AFB, AZ 85224

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ABSTRACT

The use of helmet mounted displays (HMDs) in flight simulation requires that different visual scenes be presented to the two eyes. Such disparate stimulation may result in perceptual problems which would adversely effect simulator training. We report here observations on several visual phenomena induced by stimulating the two eyes with different light intensities and spectra. The results have implications for HMD design as well as for theories of rivalry-suppression and motion perception.

In these experiments, selective rivalry-suppression and motion aftereffects of binocular viewing of dynamic noise were investigated. Observers viewed dynamic visual noise binocularly with a red filter placed over one eye. Depth and coherent motion of two counterdirectional planes of dots, similar to those reported with neutral density filters, were seen. With the red filter placed over the dominant eye, binocular rivalry resulted, causing an alternating appearance between red and grey of the display. However, the perception of movement and depth persisted during the entire cycle of the rivalry (further established in a red-blue rivalry paradigm). These observations provide evidence that the rivalry-suppression induced by color difference is selective and does not include movement-in-depth.

While fixating on and attending to one of the two moving planes, the filter was suddenly removed. All observers reported a motion aftereffect in a direction opposite to that of the attended movement plane. The duration of this short-lived aftereffect was independent of the time spent viewing the induced field, and no depth perception was associated with the movement aftereffect. This implies that depth and movement information which are coupled under the stimulus conditions providing movement-in-depth are decoupled before the processing stage responsible for movement adaptation.

INTRODUCTION

This facet of our basic research was motivated by a concern for possible perceptual problems associated with the use of binocular imagery in advanced simulators for pilot training (ASPT), utlizing the technology of area of interest helmet-mounted display (AOI/HMD). Such a system provides the observer with separate, overlapping, high resolution channels to the two eyes. In the monocular version of AOI/HMD, there is only one high resolution channel for the dominant eye (Fig. 1). The image of the insert on the right eye channel is, in this case, a higher resolution version of the AOI portion of the wide field display. Such an imagery configuration could cause perceptual problems. One such problem has been addressed in the literature -- i.e., the problem of binocular rivalryinduced by disparate images presented tothe two eyes when the HMD is used. The main problem with this approach of studying the rivalrous effects of complex imagery is the difficulty in identifying the aspects of the image that are inducing and controlling the rivalry.

In the present series of experiments we intended to study both binocular rivalry and perceptual effects of motion-in-depth, and chose the syntax-free stimulus of dynamic visual noise (DVN). The experimental paradigm we used was the DVN stereophenomenon induced by interocular intensity difference.

A perception of depth and coherent motion results if an interocular intensity difference is introduced during the binocular viewing of dynamic visual noise (Ross, 1974; Tyler, 1974), under these conditions, most observers perceive two planes of moving dots (or texture) as depicted in Figure 2. These observations have been the subject of numerous studies designed to establish the stimulus conditions which elicit them (Tyler, 1974; 1977; Mezrich and Rose, 1977; Falk and Williams, 1980). Although the question of the origin of this phenomenon makes it potentially relevant to the study of other perceptual phenomena dependent on binocular interaction. We describe here only observations on binocular rivalry and a movement aftereffect induced by viewing dynamic visual noise with an interocular intensity difference produced by placing different light attenuating

SELECTIVE RIVALRY SUPPRESSION

The results of several studies suggest that binocular rivalry suppression is essentially non-selective in that several aspects of the visual stimulus are suppressed simultaneously (Fox and Check, 1968; Blake and Fox, 1974; Hollins and Leung, 1978). However, Treismann (1978) has shown that in the case of static visual information, with respect to chromaticity, rivalry suppression is selective. The following experiments were performed to determine whether the rivalry supression elicited by presenting differently colored stimuli to the two eyes would also suppress the information necessary to produce the centrally (i.e. binocularly) mediated perception of movement-in-depth (Ross, 1974; Tyler, 1974).

Ten observers viewed dynamic visual noise produced by a detuned television receiver as shown in Fig. 2 (mean luminance = 28 ft-L). When a red (Wratten #26) filter was placed over one eye all observers reported the appearance of two planes of dots -- one in front of the plane of the television screen and moving in the direction of the filtered eye, while the other was recessed and moving in the direction of the unfiltered eye. Further, with the red filter placed over the observers non-domonant eye, binocular rivalry resulted causing an alternating appearance between gray and red of the display. It proved difficult for the observers to judge whether the gray seen by the unfiltered eye was ever completely suppressed; that is, to judge the saturation of the red display. However, all observers reported with confidence that there was no trace of red in the display when the non-dominant (filtered) eye was suppressed. The percentage of the time that this occurred in each of ten one-minute intervals is shown in Fig. 3. Typically, complete color suppression occurred for three to seven seconds out of each one-minute interval. By comparison movement-in-depth persisted during the entire cycle of rivalry (further established in red-blue rivalry paradigm). The results indicate that the rivalry suppression induced by color difference is selective in that chromatic information from one eye can be suppressed while the luminance information which contributes to the perception of movement-in-depth is not suppressed. This further supports and extends Triesmann's findings.

MOTION AFTEREFFECT

In the second experiment the perception of movement-in-depth was induced by asking eight observers to again view the television-produced dynamic visual noise, this time with a 1.5 log unit neutral density filter (Wratten #96) placed over one eye. Under this condition the observers reported the same movement-in-depth as was perceived with the red filter placed over one eye. The observers were next instructed to fixate on and attend to the plane whose texture and motion were most vivid. After about one minute of viewing, the observers were asked to remove the neutral density filter and report whether any coherent motion could be seen and if so what was its direction and magnitude. All eight observers reported a motion aftereffect in a direction opposite to that of the attended movement plane. Consistent with Papert's (1969) observations, the motion aftereffect was not always seen by all observers. When it was seen it was relatively short-lived (1-2 sec.) and its duration appeared to be indepndent of the time spent viewing the movement which induced it. An estimate of the amplitude of the motion aftereffect was obtained, from four of the eight observers, by using a large beamsplitter to superimpose on the DVN display a drifting square wave modulated dashed-line whose drift velocity could be adjusted by the observer (Fig. 4). The drifting dashed-line was produced by removing the vertical input from a raster generator (Innisfree Inc) of a square-wave grating displayed on a Tektronix Model 608 monitor.

The velocity of the motion aftereffect was estimated by all four observers to be the same or slightly higher than that of the inducing field (for the given N.D. filter of 1.5 log units). Further quantitative comparison of movement and movement aftereffect velocities, obtained for various values of N.D., indicates that the aftereffect-velocity changed much less as a function of attentuation than did the movement velocity which induced it (Fig. 5). Furthermore, the aftereffect velocity tends toward a value in the midrange of velocities attained under these viewing conditions. There are also several qualitative differences between real (peripheral apparent motion) and centrally produced (cognitive apparent motion) aftereffects. Our observations are similar to those of Papert (1964) and can be summarized as follows: Real movement aftereffects tend to be persistent and are perceived consistently. Perhaps because they are persistent and strong they can sometimes be disorienting or distracting. Also, real movement aftereffects are dependent on inducing time. By comparison, centrally produced movement aftereffects tend to be short (one-two seconds at most) and they are sporadically perceived (not everyone sees them, and those who do, don't see them all the time). They are not dependent on inducing time, although some minimum duration is required for induction.

There was one additional interesting observation on the aftereffect. Although 80% of the observers reported seeing the movement aftereffect, no observer ever reported seeing a depth aftereffect. This would seem to imply that the neural substrate mediating movement-in-depth precedes that involved in movement adaptation.Putting it differently, this observation implies that depth and movement information, which are coupled under the stimulus conditions producing movement-in-depth, are decoupled before processing at the neural stage responsible for movement adaptation. Further, it is important to note that whereas there are two predominant planes of movement in the adapting field, there is only one in the motion aftereffect. This seems to suggest that attention permits preselection of one of the two counter directionally moving planes.

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Ross, J. Stereopsis by binocular delay. Nature 248,363, 1974.

FIGURE CAPTIONS

Figure 1: Illustration of a monocular version of the area of interest helmet-mounted display (AOI/HMD).

Figure 2: Illustration of motion-in-depth induced by viewing a detuned television with interocular intensity difference.

Figure 3: Percentage of time of color suppression and of movement-in-depth perception in each of ten one-minute intervals.

Figure 4: Schematic diagram of the setup used in estimation of induced movement velocity. With the beamsplitter rotated by 90°, the optometer can be used for estimation of the refractive state of the left eye.

Figure 5: Movement-effect velocity (a) and movement-aftereffect velocity (b) as a function of interocular relative luminance difference. The two are superimposed in (c) for comparison.

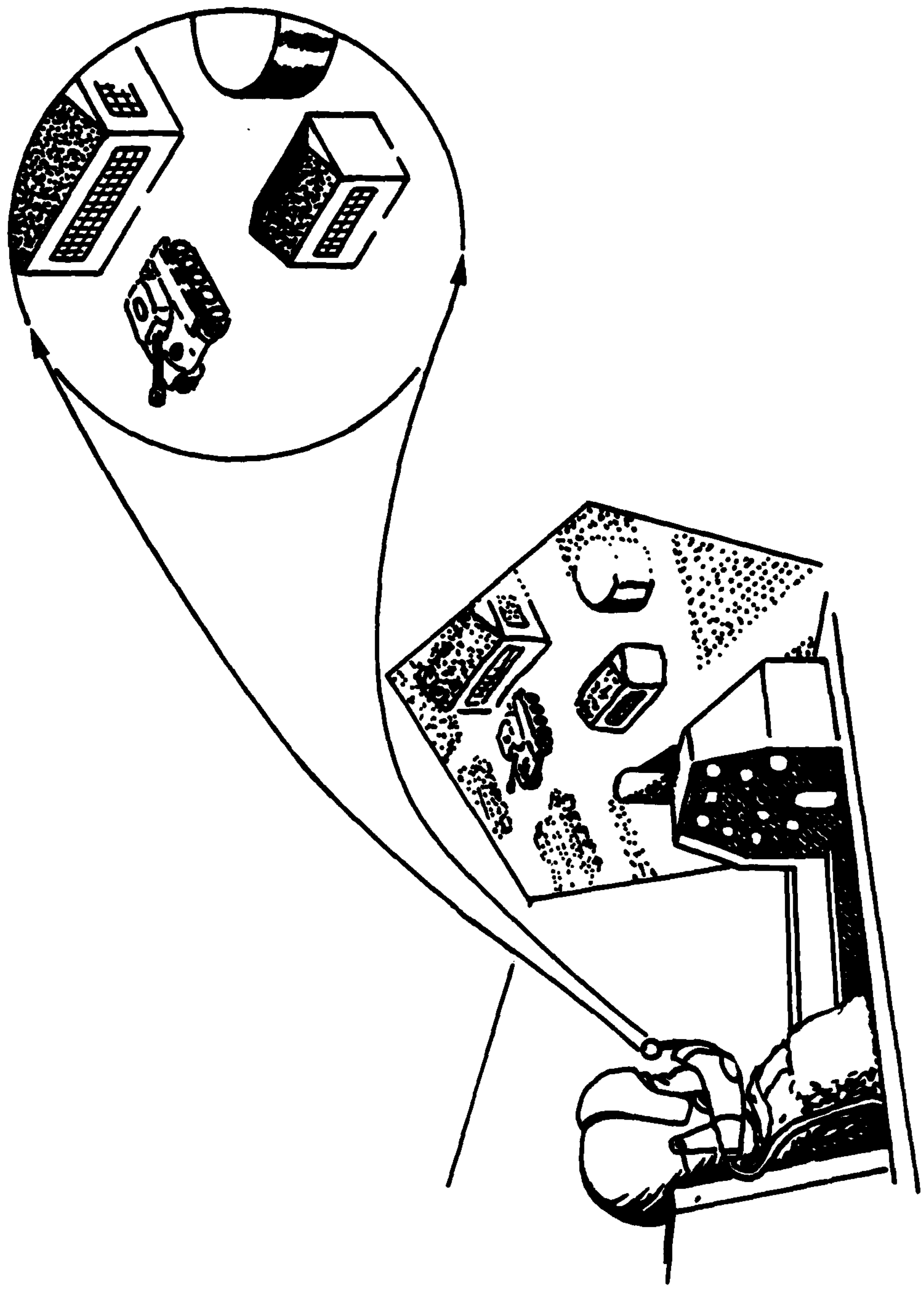
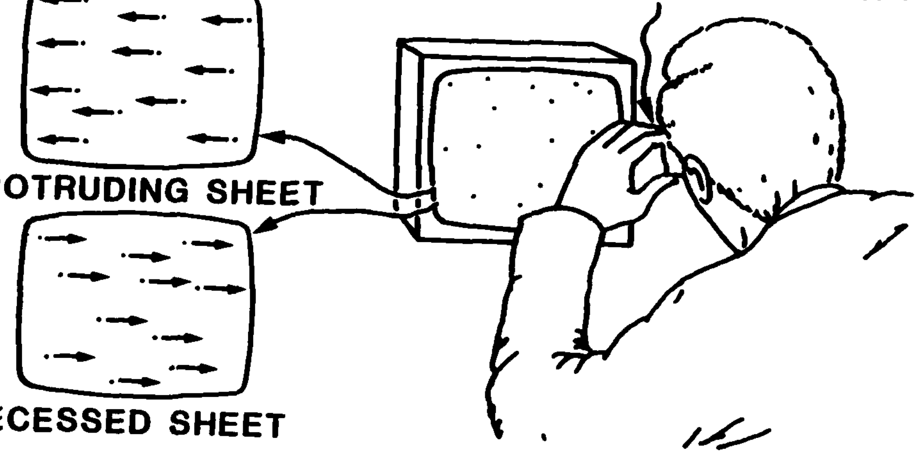


Figure 1



APPARENT DEPTH AND MOTION IN TELEVISION "SNOW"

Figure 2

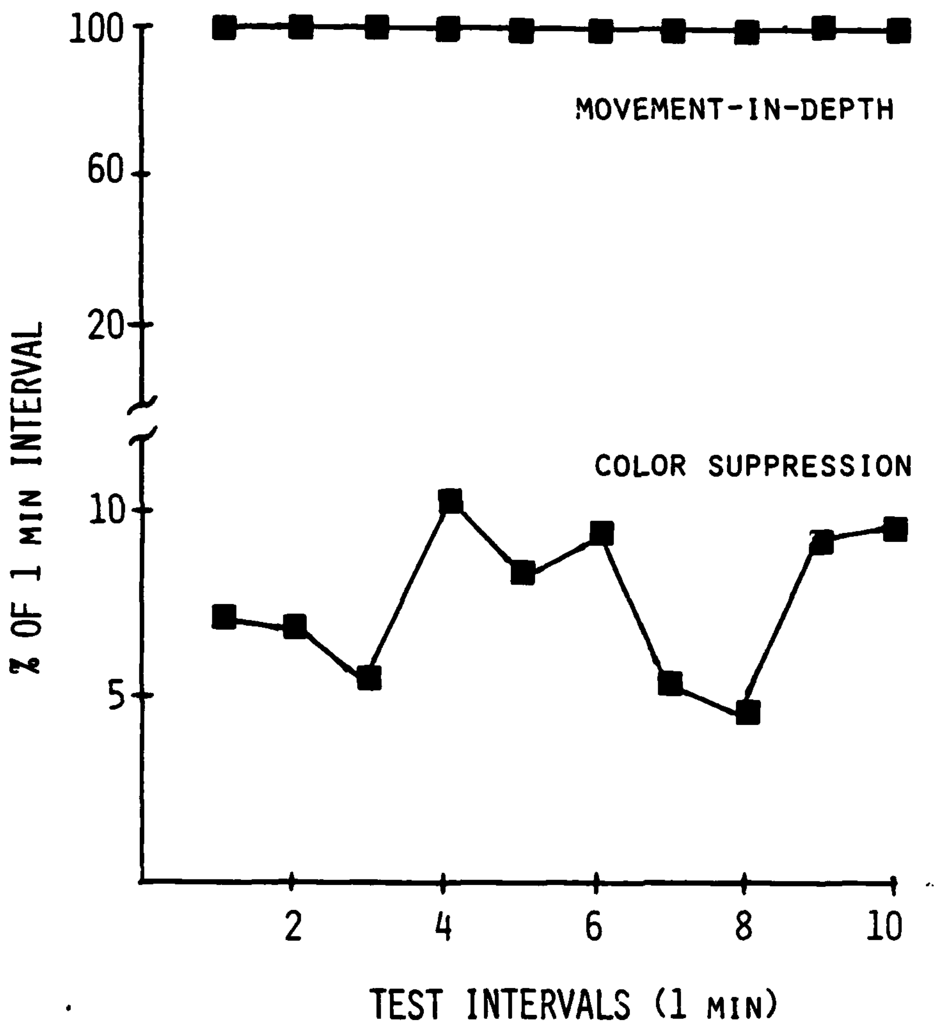

100
60
20
10
5
MOVEMENT-IN-DEPTH
COLOR SUPPRESSION
% OF 1 MIN INTERVAL
2
4
6
8
10
TEST INTERVALS (1 MIN)

Figure 3

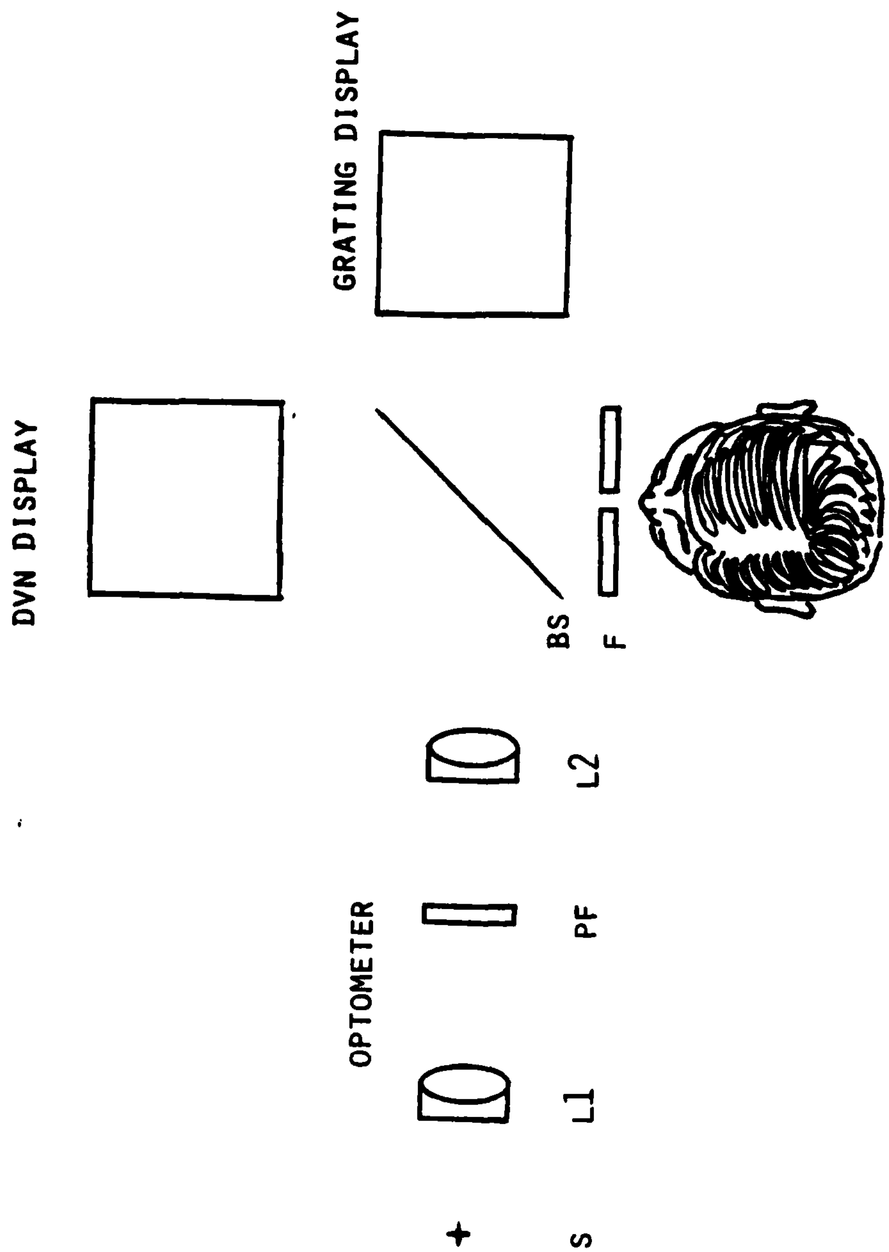


Figure 4

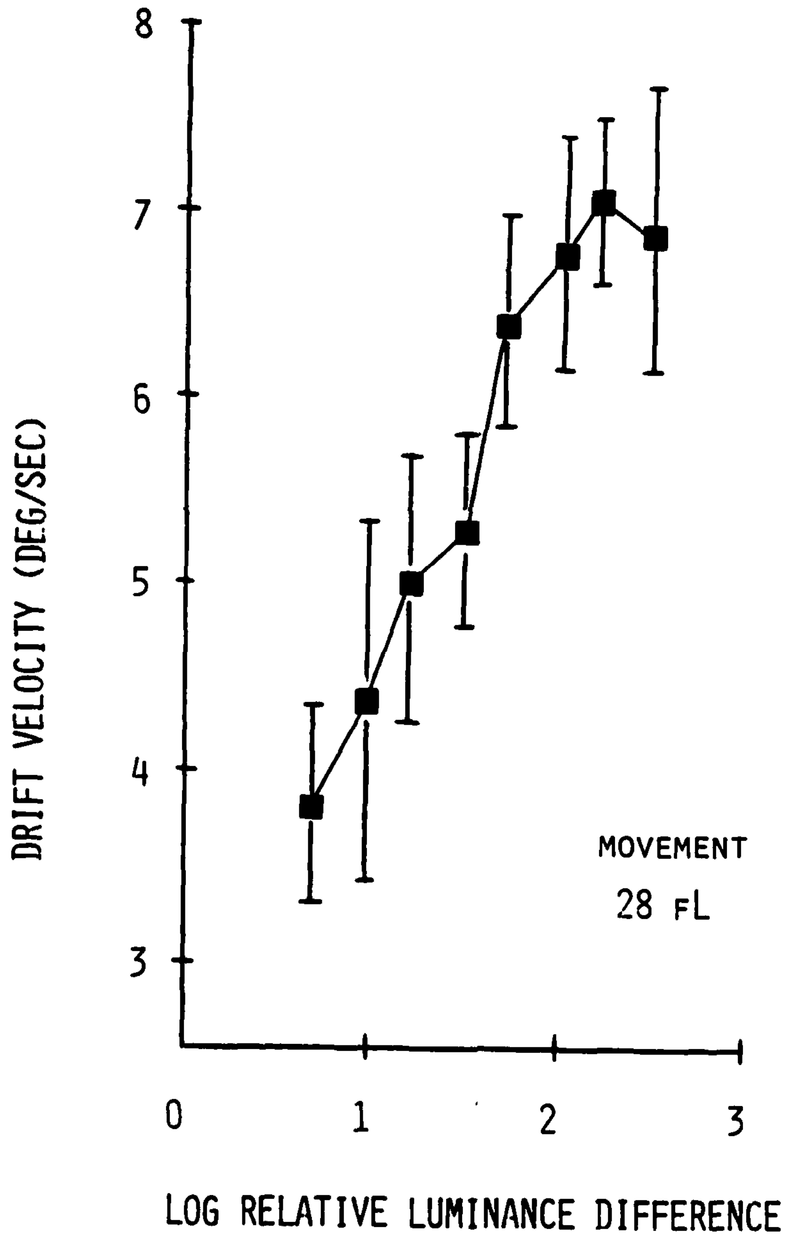

8
7
6
5
4
3
DRIFT VELOCITY (DEG/SEC)
MOVEMENT
28 FL
0
1
2
3
LOG RELATIVE LUMINANCE DIFFERENCE

Figure 5a

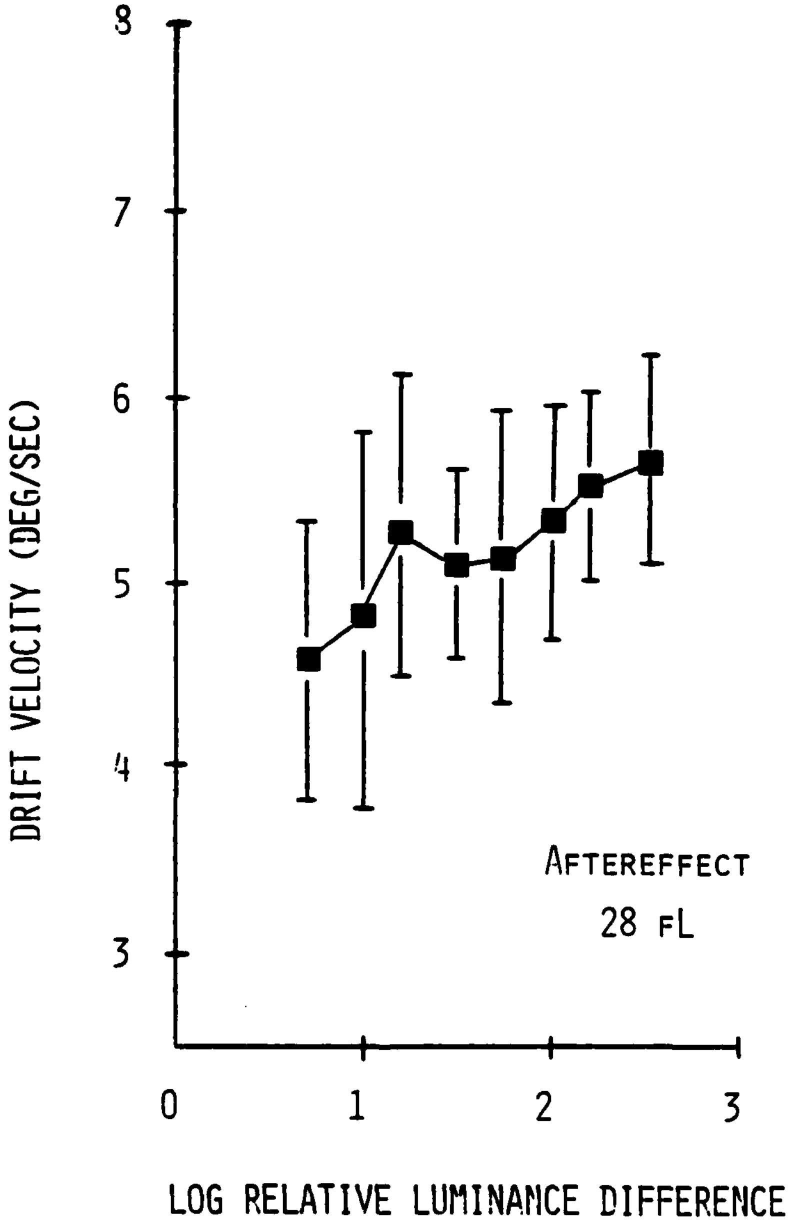

8
7
6
5
4
3
DRIFT VELOCITY (DEG/SEC)
AFTEREFFECT
28 FL
0
1
2
3
LOG RELATIVE LUMINANCE DIFFERENCE

Figure 5b

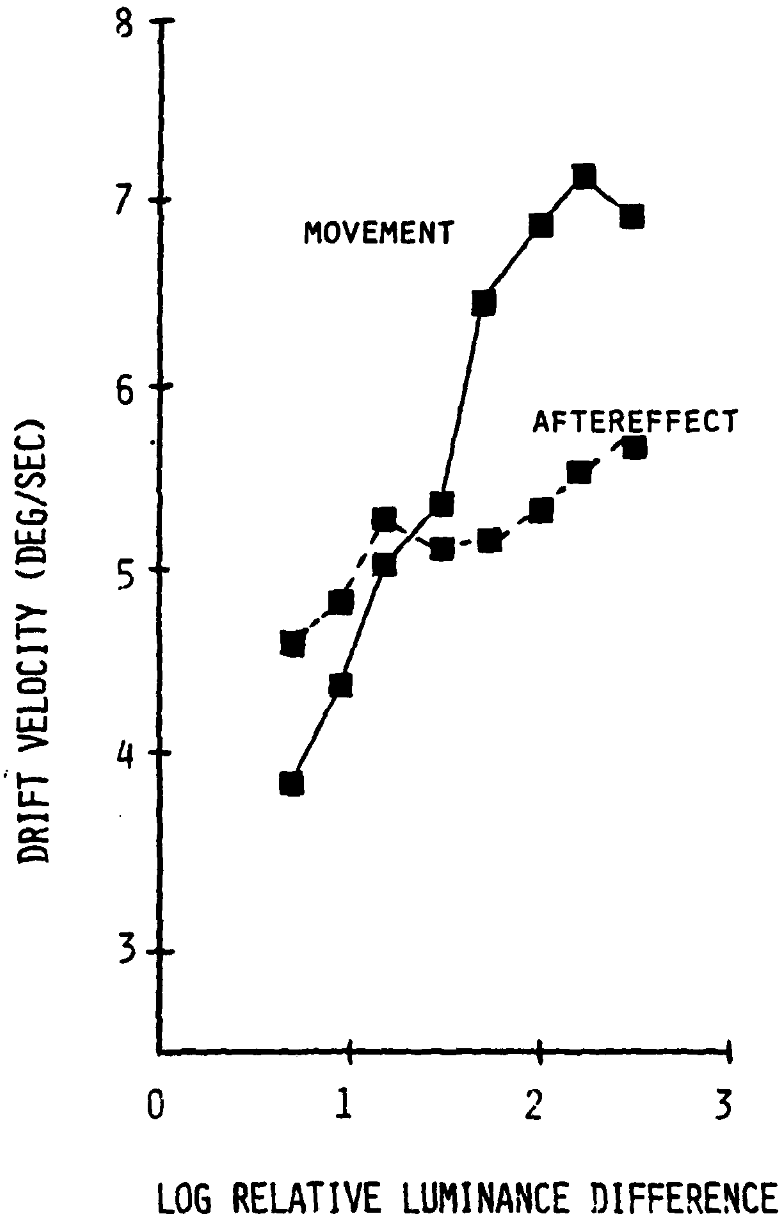

8
7
6
5
4
3
DRIFT VELOCITY (DEG/SEC)
MOVEMENT
AFTEREFFECT
0
1
2
3
LOG RELATIVE LUMINANCE DIFFERENCE

Figure 5c

APPENDIX

OPTICAL SOCIETY OF AMERICA

ANNUAL MEETING ABSTRACTS

TuC7. Masking Effects on Visual Target Detection and Tracking.* Y. Y. ZEEVI, T. N. LONGRIDGE,† AND J. C. DE MAIO,† *Man Vehicle Laboratory, Massachusetts Institute of Technology, Cambridge, Mass. 02139.*—Since eye movements are required for the detection and tracking of a point target, their concomitant signal can provide physiological objective measures of performance in target acquisition tasks. Saccadic latency, misses, and false alarm rate were used in assessing and comparing the effects of static and dynamic masks on target detection and tracking. A point target with an effective diameter of 0.4° was displayed in either of two fixed positions separated by 18° symmetrically with respect to the egocentric axis. Timing of target displacement was either periodic, and as such may have affected predictive control, or aperiodic. Masking field was generated by projection of a polarized texture pattern characterized by spatial spectrum below 1 cpd, superimposed on the visual axis via a beam splitter. Masking dynamics were generated by a rotating polarizer situated in front of the masking field projector. As target luminance decreased from 11 to 6 fL, reaction time measured as saccadic latency increased. This effect of target luminance was further substantiated once static masking was introduced. Aperiodic target displacements resulted in false alarm saccades to the right position. It was found that dynamic mask of the same spatial spectrum and contrast had a significantly more detrimental effect on subject performance. This was manifested by longer reaction times and higher rates of misses and false alarms. (13 min.)

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† Air Force Human Resources Laboratory, Williams Air Force Base, Ariz. 85224.

SELECTIVE RIVALRY SUPPRESSION AND MOTION AFTEREFFECT IN BINOCULAR VIEWING OF DYNAMIC NOISE. Y.Y. Zeevi, G.A. Geri* and and T.M. Longridge*, Man Vehicle Laboratory, M.I.T., Cambridge, MA 02139

Observers viewed dynamic visual noise binocularly with a red filter placed over one eye. Depth and coherent motion of two counter-directional planes of dots, similar to those reported with neutral density filters, were seen. With the red filter over the dominant eye, binocular rivalry resulted, causing an alternating appearance between grey and red of the display. However, the perception of movement and depth persisted during the entire cycle of the rivalry (further established in a red-blue rivalry paradigm). These observations provide evidence that the rivalry-suppression induced by color difference is selective and does not include movement in-depth.

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* AFHRL/OT Williams AFB, AZ

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